Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #15
(January 3 to March 11, 2008**)**

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PREFACE

The Halifax Harbour Water Quality Monitoring Project (HHWQMP) is an ongoing project, part of the Halifax Harbour Solutions Project (HRM and JWEL, 2002). It commenced in June 2004, before any of the proposed sewage treatment changes were put into effect, and is slated to continue for a year following the commission of the final plant (June 2009). The project is based on water quality surveys that include over 30 sites distributed from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1 m and 10 m depths are analyzed for a range of parameters. In addition, continuous profiles of basic hydrographic properties (salinity, temperature and density), dissolved oxygen and fluorescence are collected. From June 2004 to June 2006 the surveys were conducted weekly and from July 2006 onward, slightly modified surveys are conducted biweekly. The sample and profile data are presented in survey reports (weekly or biweekly, as appropriate) along with ancillary data including water level, wind, rainfall and other parameters. The reports are generated as inserts into a binder (JWEL and COA, 2004). Electronic copies of the reports and data files are also delivered to the client. A detailed description of the program is contained in the introduction section of the report binder.

The weekly/biweekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly/biweekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program. Project reports and data are available on the Halifax Regional Municipality (HRM) website:
http://www.halifax.ca/harboursol/waterqualitydata.html

The HHWQMP program involves an extensive network of personnel including boat operators, field technicians, laboratory technicians and their associated equipment and procedures. The study team also includes managers, oceanographers and water quality experts. The routines, procedures, report and data archive formats are evolving as the project proceeds. These are documented in the project report binder.

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1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 3 January to 11 March 2008 (surveys 146 to 151). The results of the individual surveys are documented in survey reports. In this report, the data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. An emphasis in this report is a continued assessment of the efficacy of the sampling program and of the potential introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data that can occur subsequently. This report discusses just the fifteenth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making each quarterly report useful as a stand-alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Reporting

The basic report format for both survey and quarterly reports is discussed in detail in the introduction of the project report binder and in Quarterly Report 1 (QR1, JWL and COA, 2004). Slight modifications and enhancements to the reports continue to be made as experience dictates. Starting with survey 151 (11 Mar 08) DO measurements are made with a handheld YSI DO meter. This is for ground truthing the Seabird DO data. The YSI data, as well as the BBPMP and LOBO data buoy data, and the data inter-comparison is added to the cover sheet of the survey data files.

In earlier quarterly reports (up to Quarterly Report 8), the data from the center of Bedford Basin (Station G2) was compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project of the Department of Fisheries and Oceans at Bedford Institute of Oceanography. The BBPMP discontinued the summary time series contour plots that were used for comparison purposes. The data is still available in the form of individual profile plots and time series plots at selected depths. Selected points from the BBPMP dissolved oxygen (DO) profiles are now compared with the HHWQMP DO data for purposes of ground truthing. The time series contour plots of the HHWQMP data in the centre of the Basin are instructive in the description of longer term variability in the harbour and are continued in the annual summary discussions in every fourth quarterly report.

From time to time, errors are discovered in the reports after they have been issued. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. In addition to errors the Errata/Changes section documents the changes in the sampling program and reporting.

3 Sampling Program

Survey sampling is done on a biweekly basis as of July 2006. Sampling is conducted from one of several vessels, operated by Connors Diving Services Ltd., based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and Quarterly Report 1. The locations of the 34 regular sampling sites are included in Figure 1. These sites are a combination of historically occupied sites (Jordan, 1972), some project specific sites and identified recreational (yacht club/beach) sites. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10 m water depth. The level of analysis varies from site to site as depicted in Figure 1: CTD only (CTD only stations); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove (DC), established in response to public concern. At this site, a 1 m water sample and profile data are obtained. The water sample is analyzed for the full suite of parameters. This site is sampled once a month during the summer. The "supplemental sample" procedure that has been established allows water samples to be taken at additional sites, based on visual observations, at the discretion of the field team.

Sampling protocol/sample handling has been dictated by experience and specific lab directions. CTD casts are performed according to the manufacturer's recommendation and data analysis follows standard procedures. These protocols are documented in the project binder with weekly and quarterly reports.

3.1 Program Changes

The DO senor on the project CTD experienced problems in the first survey of the quarter. The sensor was removed from the CTD and returned to the manufacturer for service. The sensor was being repaired/serviced for the following three surveys. During this period a handheld YSI DO probe was used to collect near surface dissolved oxygen data. Upon return of the sensor it continued to experience stability problems for the last two surveys. The auxiliary YSI data was continued as ground truth, augmenting the comparison with the BBPMP data in the weekly surveys. This ground truthing will continue henceforth.

A summary of the sampling and analysis schedules and relevant established criteria in place at the end of eleventh quarter (13 March 2007) are in Table 1. This table indicates that the carbonaceous biochemical oxygen demand (BOD_5) and total oil and grease (TOG) analyses, discontinued from regular sampling due to lack detection, are now performed only for "supplemental samples".

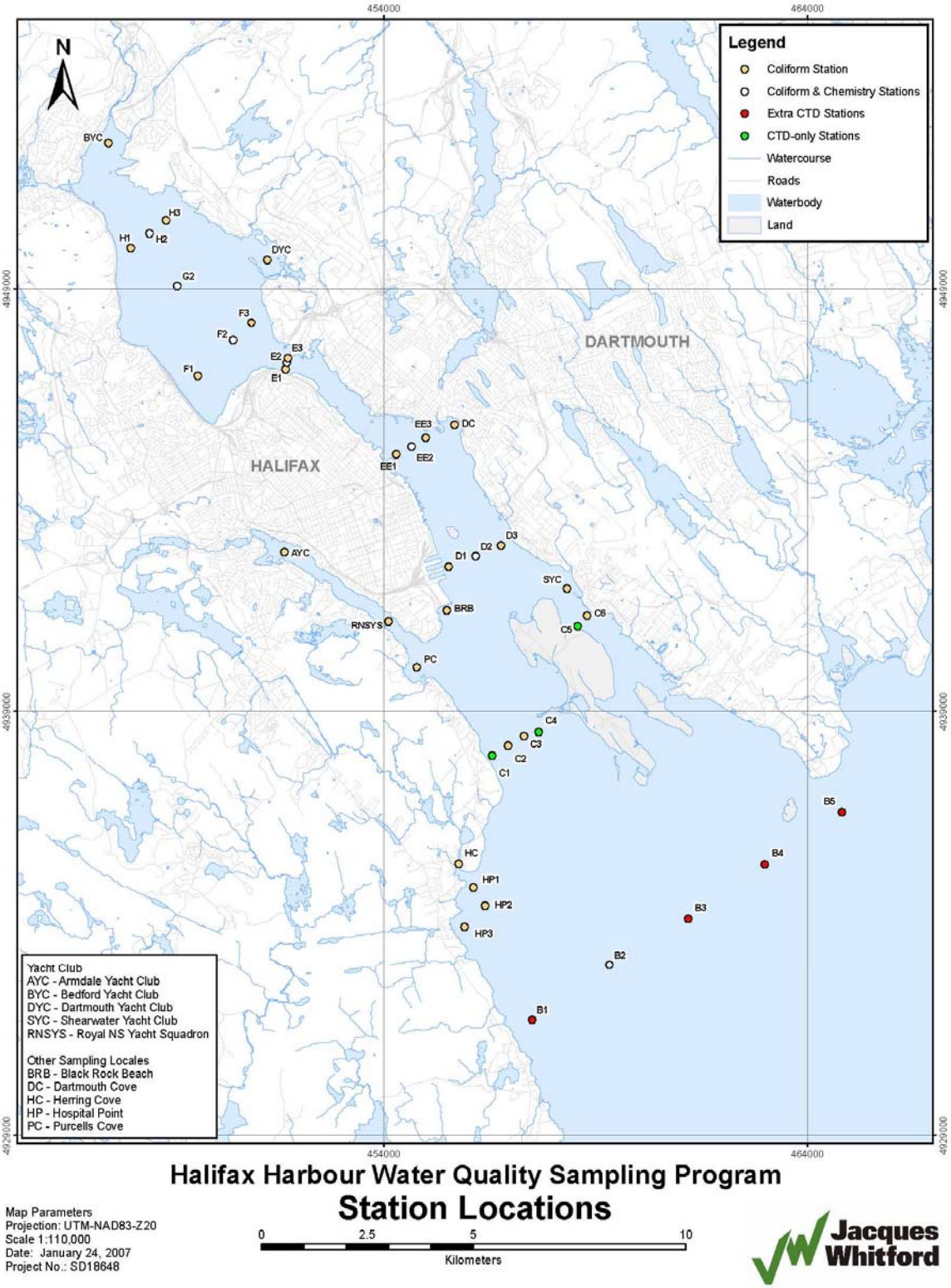

Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 11 March 2008.

	RDL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	biweekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	ug/L	n/a	n/a		
			8	SA		
Dissolved Oxygen	n/a	mg/L	7	SB		
			6	SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	biweekly
Fecal Coliform	1	cfu/ 100mL	14	SA		
			200	SB		
			none	SC		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
			<10%			
TSS	0.5	mg/L	background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan						bi-weekly
Cadmium	0.1	ug/L	9.3	all	Chemical sites	
Copper	0.1	ug/L	2.9	all	Chemical sites	
Lead	0.1	ug/L	5.6	all	Chemical sites	
Manganese	1	ug/L	100.0	all	Chemical sites	
Nickel	0.5	ug/L	8.3	all	Chemical sites	
Zinc	1	ug/L	86.0	all	Chemical sites	
Mercury	0.01	ug/L	0.025	all	Chemical sites	
Cobalt	0.1	ug/L	none		Chemical sites	
Iron	1	ug/L	none		Chemical sites	

3.2 Supplemental Samples

Based on recommendations from Quarterly Report 2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour, or to document unusual discharge conditions (e.g. bypass etc). These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front, plume, or patch of visibly deteriorated water quality is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters which have been eliminated from normal sampling due to lack of detection. During this quarter, in Survey 150 (26 Feb 08) there was a supplemental sample of a visible feature at the Halifax STP outfall (section 4.8).

3.3 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every survey the sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight. A variable circuit is used that results in 'quasi' random sampling, subject to certain operational constraints. This procedure is discussed in Quarterly Report 1. Wind, waves and visibility can limit operations in the Outer Harbour. Each week, a primary and an alternate sampling route are provided to the field team. If the primary route has the Outer Harbour sampled early in the day, the alternate route will have it sampled late in the program. The decision on which route to take is made between the field team and the boat operator considering the weather forecast for the day. The sampling order for each survey in the fifteenth quarter is presented in Table 2.

Also, Table 2 lists the missed stations and additional samples (described above) for each survey. During this quarter, DYC was missed due to ice on survey 150 (26 Feb 08) and sites SYC, C5, C6, C2, H1 were missed in Survey 151 (11 Mar 08). That day a sediment sampling team from Dalhousie University was on board resulting in additional time constraints.

3.4 Data Return

In addition to the missed sites detailed above, there were other sporadic data losses generally associated with quality control issues that were discovered during data processing. This quarter there were particular issues with the DO sensor on the CTD. It was malfunctioning, resulting in data loss, and was ultimately sent out for repair/calibration. This resulted in three surveys without dissolved oxygen profiles (surface values were taken with an alternate instrument). These are discussed in the individual survey reports. All factors considered, the overall data return for the quarter is summarized in Table 3.

3.5 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites, that is, whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the Harbour. Our sampling has operational constraints that introduce a morning/early afternoon bias to the entire dataset. It is impractical to address this fully, except to document it. The following section is a first look at potential bias with respect to time of day, water level, and rainfall during the fifteenth quarter.

Table 2. Sample collection order (green sites are CTD only).

Date	3-Jan-08	15-Jan-08	30-Jan-08	12-Feb-08	26-Feb-08	11-Mar-08
Survey	146	147	148	149	150	151
1	AYC	C1	AYC	SYC	AYC	D3
2	RNSYS	C2	RNSYS	C6	RNSYS	D2
3	PC	HC	PC	C5	PC	C4
4	C4	HP1	BRB	D3	BRB	C3
5	C3	HP2	C2	D2	D3	B2
6	B2	HP3	C1	EE3	SYC	HP3
7	HP3	B2	HC	EE2	C6	HP2
8	HP2	C3	HP1	E3	C5	HP1
9	HP1	C4	HP2	E1	C4	HC
10	HC	C5	HP3	E2	C3	C1
11	C1	C6	B2	F3	B2	BRB
12	C2	SYS	C3	F2	HP3	D1
13	BRB	D3	C4	DYC	HP2	EE1
14	D1	EE3	C5	H3	HP1	EE2
15	EE1	E3	C6	H2	HC	EE3
16	F1	E1	SYC	BYC	C1	E1
17	G2	E2	D3	H1	C2	E3
18	BYC	F3	D2	G2	D1	E2
19	H3	DYC	EE3	F1	D2	F1
20	H2	H3	EE2	EE1	EE1	F2
21	DYC	BYC	E3	D1	EE2	F3
22	H1	H1	E1	BRB	E3	DYC
23	F3	H2	E2	C2	E1	G2
24	F2	G2	F2	C1	E2	BYC
25	E1	F1	F3	HC	F2	H3
26	E3	F2	DYC (	HP1	F1	H2
27	E2	EE1	H3	HP2	G2	PC
28	EE3	EE2	H2	HP3	H1	RNSYS
29	EE2	D1	BYC	B2	H2	AYC
30	D3	D2	H1	C3	BYC	
31	D2	BRB	G2	C4	H3	
32	SYC	PC	F1	PC	F3	
33	C6	RNSYS	EE1	RNSYS	EE3	
34	C5	AYC	D1	AYC		
No data					DYC	SYC,C5,C6,C2,H1
Supplemental					Halifax STP	

Table 3. Quarter fifteen data return.

Chemical	Target	Achieved	Percent Return
7 sites			
NH3	84	84	
TSS	84	84	
Metal Suite	84	84	
Mercury	84	84	
Total	**336**	**336**	**100%**

Bacteria	Target	Achieved	
28 sites			
F Coliform	372	362	
Total	**372**	**362**	**97%**

Profiles	Target	Achieved	
31 sites			
C-T	204	193	
Dissolved Oxygen	204	84	
Chlorophyll	204	193	
Total	**612**	**470**	**77%**
All data records	**1320**	**1168**	**88%**

3.5.1 Time of Day

Sewage flows have significant regular diurnal variations that can affect the water quality in the Harbour on short timescales. In residential areas there are generally two flow peaks a day, the largest occurring in the morning, and the second in the evening. In systems with relatively short flow distances these generally occur around 0800 – 0900 and 2100. In commercial areas the flows are much more uniform during the day and low at night. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (fluorescence) and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, however sunlight affects the entire Harbour. In Halifax there is also a significant diurnal tidal component affecting water levels. This is considered in the subsequent section.

Figure 2 shows the sampling time at each site since the start of the program in June 2004. The data from the fifteenth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge that have been documented previously. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south, a

function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable.

The diagram indicates that overall there has been a morning bias in the Outer Harbour Stations, a result of weather conditions this quarter. This creates an afternoon bias in the remainder of the data. This is strongest in the Basin and Narrows (section E). In the remainder of the Inner Harbour sampling is relatively uniformly distributed. The D1 and E1 sites are an exception, not being sampled before about 11:00. The Northwest Arm that has a built in early morning/late afternoon bias had an even spit between morning and afternoon surveys.

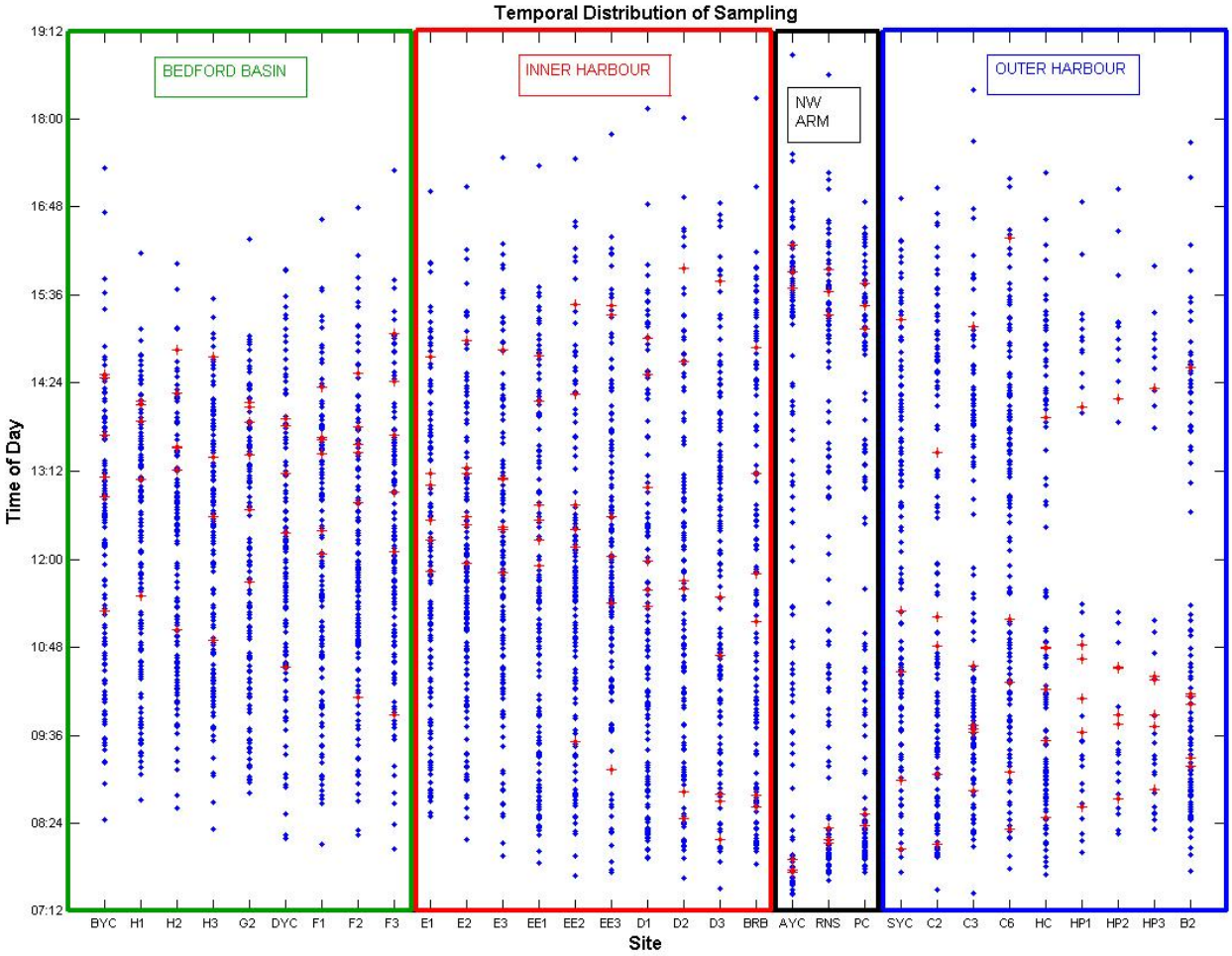

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 3 January to 11 March 2008.

3.5.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious considerations are whether a particular sample was taken upstream or downstream (based on flood/ebb direction) from the nearest outfall, and the variation in initial dilution, caused by variations in submergence depth, from shallow shoreline outfalls. These are both issues primarily in the Inner Harbour.

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are mostly of longer period and, except in large storms, are much smaller in magnitude than the tides. Because of their longer duration, their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. Note that the tidal currents in the Harbour are, for the most part, not that strong and may be overridden by local/regional meteorological effects (Hurlbut et al., 1990). This means, for example, that the surface current may not always be going out on a falling tide. However, the occurrence of surges is relatively random and the possibility of inducing a systematic sampling bias is small compared with that of the very regular higher frequency tides. The tides in Halifax Harbour are classified as semidiurnal, meaning that there are two high and two low tides in a day.

There is also a potential bias introduced by regular weekly/biweekly sampling. Sampling that occurs on the same day every second week could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed"), that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue will be monitored and may be revisited more rigorously at a later time.

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period January to March 2008 is shown in Figure 3. In an ideal situation each site would be sampled in a distribution similar to the overall baseline distribution. Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, as represented by the red line recreated from Figure 3.

This shows that for this quarter, in the Basin the water level distribution is relatively well represented. In the Inner Harbour the sampling distribution is biased toward higher water levels at some sites, while in the NW Arm there is an overall bias toward lower water levels. The sampling in the Outer Harbour is relatively representative. Because sampling has been switched to bi-weekly, the number of samples in a quarter has been roughly halved. Therefore a somewhat deteriorated representation of the water level range is inevitable. If more detailed analysis is performed, particularly in the Inner Harbour where water level/tidal phase is more important, the analysis may have to include the tidal phase explicitly.

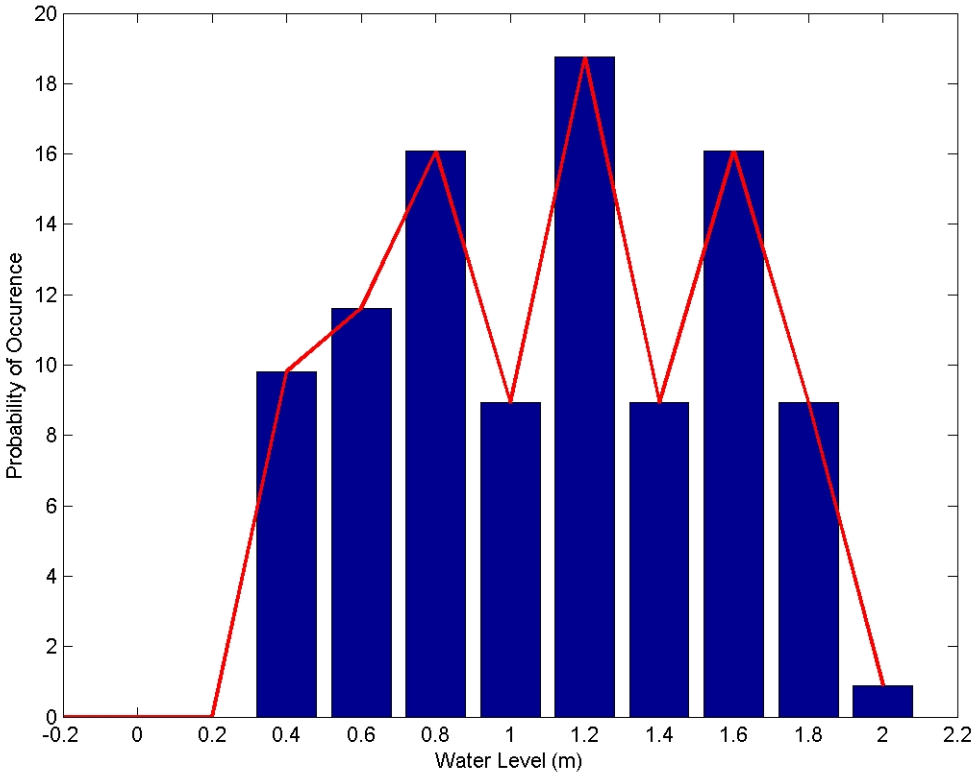

Figure 3. Probability distribution of water levels in Halifax, January to March 2008.

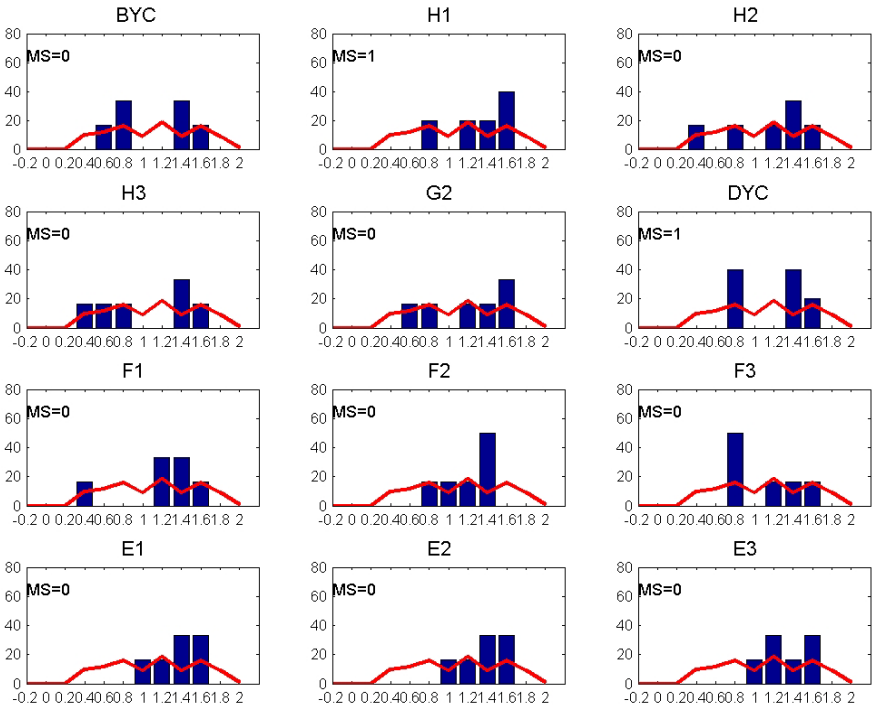

Figure 4a. Water level distribution at each site during sampling 3 January to 11 March 2008. Note: MS = Missed samples.

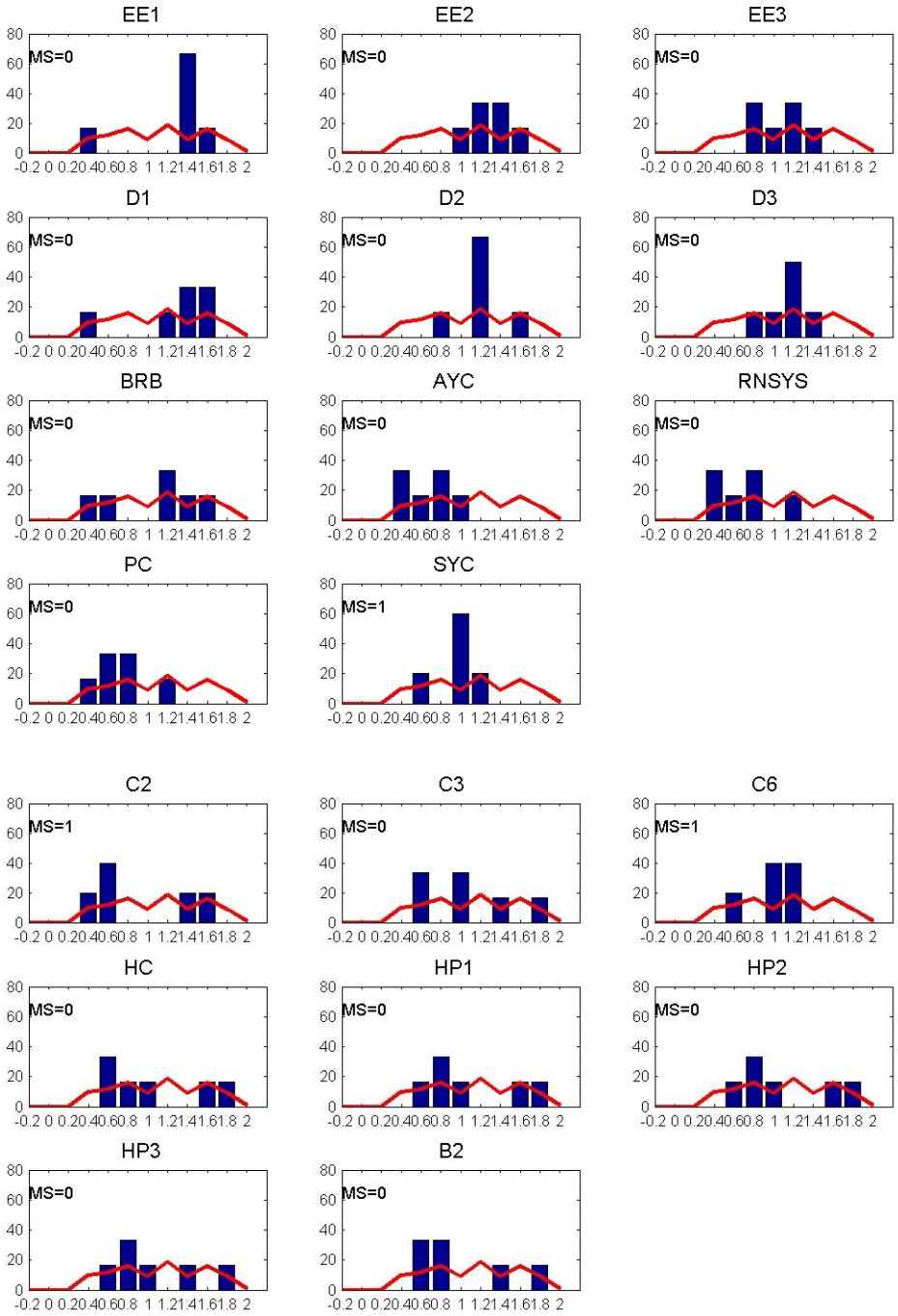

Figure 4b. Water level distribution at each site during sampling 3 January to 11 March 2008. Note: MS = Missed samples.

3.5.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. In a combined sewer system, like in Halifax, increased flow due to a rainfall event can mobilize material that has collected in the sewer pipes in low flow conditions resulting in quite high loads. Additionally, in response to the increased fresh water input, the harbour can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a significant effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period of time after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (3 January 2008 through 11 March 2008). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been biased toward ”damp” weather. Days with no precipitation for the previous 72 hours occurred 30% of the time but represent only 17% of the sampling days. On the other end there were wet weather periods, up to 45 mm, that were also not sampled.

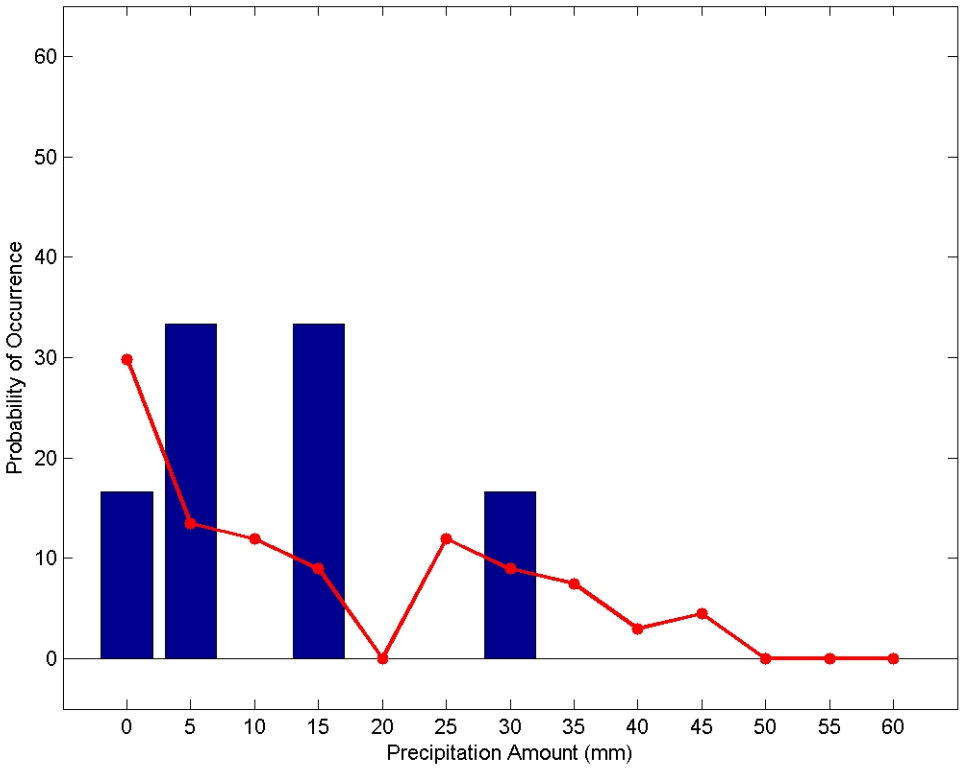

Figure 5. Probability distribution of cumulative 72 hour rainfall, 3 January to 11 March 2008.

4 Water Quality Results and Discussion

Results of the water quality sampling are discussed in the following sections with emphasis on compliance with water quality guidelines, and any need for modifications to the program. At the start of this quarter the STP connections along the Harbour waterfront have been completed. By the middle of this quarter the connections of the pumping stations in the NW are completed. The plant is functioning, but the UV disinfection system is operating sporadically.

4.1 Fecal Coliform

4.1.1 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there are no out-of-range values.

4.1.2 Quarterly Means

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with bacterial water quality criteria based on geometric mean. The geometric mean, G, of n values is defined as:

$$G(x_1,x_2,x_3,\ldots,x_n) = (x_1 \cdot x_2 \cdot x_3 \cdot \ldots \cdot x_n)^{1/n}$$

To compute geometric mean, some adjustments to the data are required. Zeros are not valid in the calculation, so ones (1's) are substituted for all zero values. The result of this is that there will be no zero counts reported at any site. An appropriate interpretation of a reported mean value of one, then, is that it is equivalent to "less than or equal to" one. Out of range values are reported by the lab as >10,000 in the units reflective of the resolution of the analysis being performed. For this analysis out of range values are replaced by 10,000.

Maps representing the geometric mean values over all samples for the fifteenth quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 cfu/100 mL); and values in green indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples.

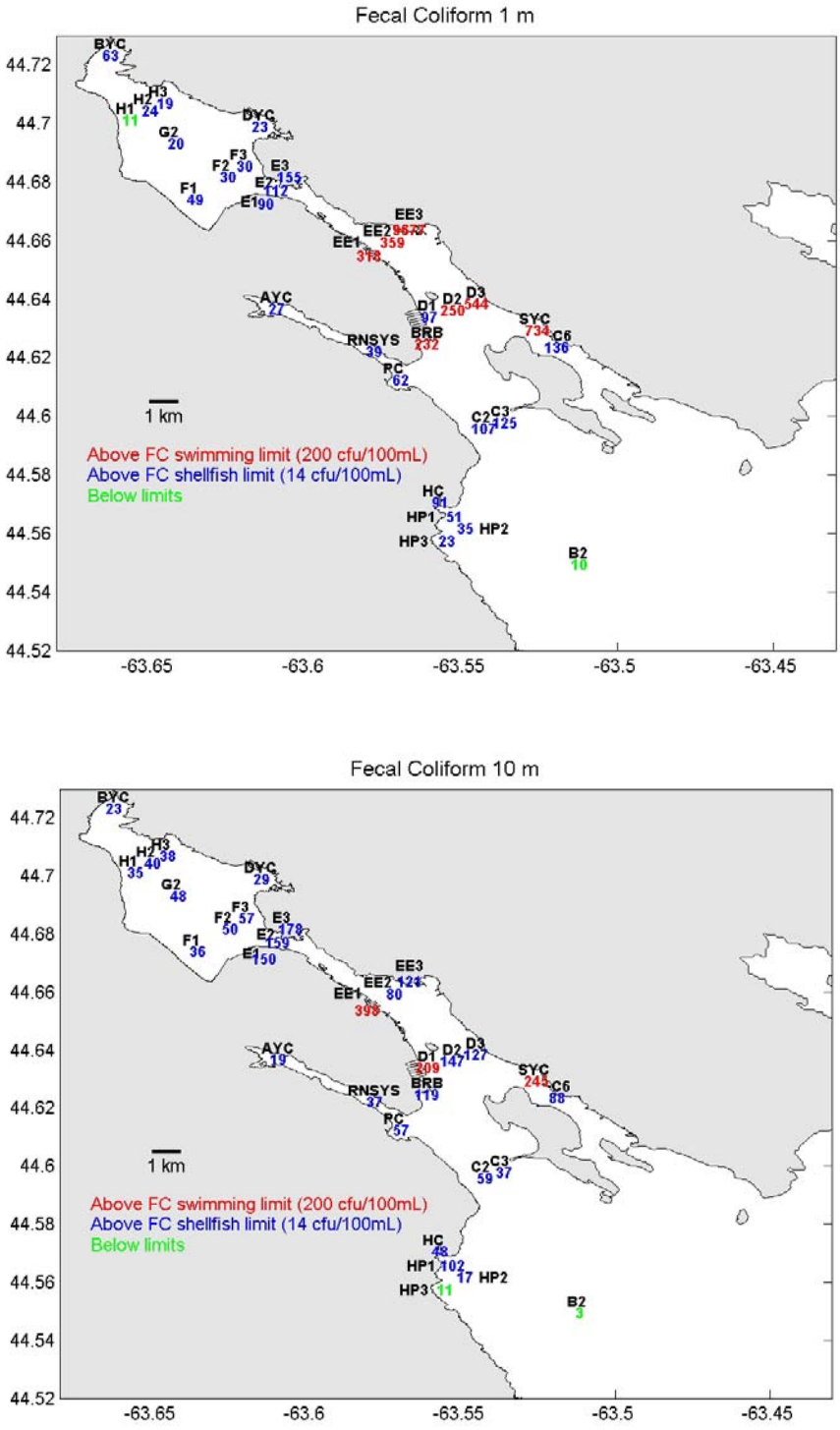

Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 3 January to 11 March 2008.

For the 1 m samples, the mean coliform levels are moderate with values greater than two hundred at sections EE and D, except anomalously for D1, and south to BRB and SYC.

There are no other areas with levels that high, though there are low but detectable levels all the way out to B2 in the Outer Harbour. The distribution in the 10m samples is remarkably similar, except the levels are generally lower. There are only two sites with levels above the 200 cfu/100mL threshold. South of the Narrows, the maximum values at any site are generally in the 1 m sample. North of the Narrows, in the Bedford Basin, the highest values are as usual, generally in the 10 m sample. However the concentrations are quite similar with depth.

The geometric mean values exceeding the swimming guidelines are mostly in the Inner Harbour, where there are no Task Force guideline limits on bacteria. A more rigorous discussion of guideline exceedance follows.

4.1.3 Guideline Exceedance

As presented in Quarterly Report 1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology for swimming areas, presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The recreational guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. This strictly applies only to areas classified SB (recreational) by the Task Force (Table 1). The implications for areas classified SA and SC are discussed subsequently. The original weekly sampling regimen resulted in five samples within 30 days and allowed a fairly rigorous application of this analysis. The change to biweekly sampling in quarter nine means that the data do not meet the criteria of five samples within 30 days. The analysis is continued using a three sample floating average to meet the 30 day window but sacrifice the five sample criteria. We feel that the analysis, though no longer a rigorous application of the criteria, remains instructive.

Interpreting this procedure in our context results in a biweekly assessment, at three levels:

1. ACCEPTABLE, defined as a geometric mean <200 cfu/100mL
2. QUESTIONABLE, geometric mean <200 cfu/100mL but one or more samples >400 cfu/100mL
3. UNACCEPTABLE, geometric mean >200 cfu/100mL.

In the following discussion the terms “acceptable”, “questionable” and “unacceptable” will refer to these primary contact levels and not the Harbour Task Force SA, SB and SC guidelines. These guidelines will be discussed subsequently.

Tables 4 and 5 show the results of the analysis for the 1 m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses,

Table 4. 30 day geometric mean (number of samples) of 1 m fecal coliform concentrations (cfu/100 ml).

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey146	21 (3)	62 (3)	35 (3)	9 (3)	201 (3)	253 (3)	86 (3)	157 (3)	205 (3)	196 (3)	217 (3)	321 (3)	295 (3)	255 (3)	176 (3)
Survey147	3 (3)	28 (3)	114 (3)	21 (3)	148 (3)	254 (3)	142 (3)	109 (3)	147 (3)	116 (3)	308 (3)	1024 (3)	266 (3)	202 (3)	201 (3)
Survey148	12 (3)	69 (3)	110 (3)	72 (3)	163 (3)	347 (3)	220 (3)	149 (3)	151 (3)	126 (3)	71 (3)	1129 (3)	236 (3)	202 (3)	263 (3)
Survey149	5 (3)	60 (3)	56 (3)	56 (3)	47 (3)	216 (3)	264 (3)	89 (3)	42 (3)	26 (3)	139 (3)	1322 (3)	191 (3)	35 (3)	468 (3)
Survey150	5 (3)	24 (3)	28 (3)	29 (3)	20 (3)	27 (3)	79 (3)	47 (3)	18 (3)	9 (3)	56 (3)	811 (3)	165 (3)	31 (3)	316 (3)
Survey151	5 (3)	21 (3)	16 (3)	22 (3)	23 (3)	7 (2)	82 (3)	16 (3)	4 (3)	2 (3)	140 (2)	822 (2)	158 (3)	22 (3)	271 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey146	432 (3)	224 (3)	199 (3)	13986 (3)	78 (3)	134 (3)	462 (3)	95 (3)	39 (3)	27 (3)	15 (3)	21 (3)	10 (3)	28 (3)	25 (3)	60 (3)
Survey147	598 (3)	365 (3)	354 (3)	12633 (3)	102 (3)	470 (2)	241 (3)	49 (3)	45 (3)	40 (3)	19 (3)	32 (3)	12 (3)	43 (3)	24 (3)	96 (3)
Survey148	441 (3)	315 (3)	291 (3)	13904 (3)	111 (3)	477 (2)	226 (3)	40 (3)	32 (3)	44 (3)	29 (3)	30 (3)	22 (3)	34 (3)	30 (3)	106 (3)
Survey149	546 (3)	363 (3)	427 (3)	14637 (3)	110 (3)	196 (2)	210 (3)	45 (3)	54 (3)	69 (3)	30 (3)	37 (3)	23 (3)	38 (3)	29 (3)	120 (3)
Survey150	596 (3)	642 (3)	511 (3)	19281 (3)	126 (3)	93 (3)	111 (3)	24 (3)	19 (3)	29 (3)	31 (2)	11 (3)	8 (3)	9 (3)	11 (3)	41 (3)
Survey151	616 (3)	355 (3)	566 (3)	5006 (3)	70 (3)	50 (3)	45 (3)	30 (3)	19 (3)	19 (3)	17 (2)	13 (3)	5 (2)	15 (3)	10 (3)	35 (3)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria.

Table 5. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (cfu/100 mL).

	Outer Harbour							Northwest Arm			Eastern Pass.		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey146	3 (3)	51 (3)	34 (3)	32 (3)	58 (3)	161 (3)	48 (3)	89 (3)	205 (3)	64 (3)	180 (3)	512 (3)	321 (3)	537 (3)	293 (3)
Survey147	3 (3)	70 (3)	38 (3)	15 (3)	37 (3)	104 (3)	57 (3)	50 (3)	118 (3)	50 (3)	199 (3)	494 (3)	201 (3)	329 (3)	278 (3)
Survey148	5 (3)	171 (3)	59 (3)	38 (3)	82 (3)	75 (3)	76 (3)	117 (3)	93 (3)	44 (3)	67 (3)	271 (3)	171 (3)	244 (3)	149 (3)
Survey149	3 (3)	225 (3)	26 (3)	13 (3)	60 (3)	58 (3)	93 (3)	112 (3)	21 (3)	17 (3)	100 (3)	311 (3)	133 (3)	257 (3)	265 (3)
Survey150	4 (3)	588 (3)	17 (3)	4 (3)	31 (3)	22 (3)	28 (3)	85 (3)	11 (3)	6 (3)	35 (3)	82 (3)	65 (3)	147 (3)	96 (3)
Survey151	3 (3)	84 (3)	3 (3)	1 (3)	17 (3)	15 (2)	14 (3)	25 (3)	6 (3)	3 (3)	48 (2)	70 (2)	41 (3)	72 (3)	63 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey146	440 (3)	223 (3)	61 (2)	123 (3)	296 (3)	188 (3)	315 (3)	28 (3)	44 (3)	32 (3)	19 (3)	38 (3)	49 (3)	46 (3)	33 (3)	28 (3)
Survey147	197 (3)	787 (3)	338 (2)	158 (3)	682 (3)	455 (3)	430 (3)	35 (3)	53 (3)	85 (3)	17 (3)	34 (3)	49 (3)	31 (3)	32 (3)	24 (3)
Survey148	112 (3)	527 (3)	269 (3)	106 (3)	502 (3)	251 (3)	194 (3)	32 (3)	42 (3)	79 (3)	24 (3)	43 (3)	30 (3)	28 (3)	26 (3)	18 (3)
Survey149	186 (3)	690 (3)	361 (3)	132 (3)	188 (3)	215 (3)	184 (3)	53 (3)	92 (3)	151 (3)	36 (3)	73 (3)	45 (3)	35 (3)	31 (3)	23 (3)
Survey150	84 (3)	360 (3)	97 (3)	170 (3)	116 (3)	130 (3)	131 (3)	48 (3)	42 (3)	71 (3)	39 (2)	55 (3)	21 (3)	31 (3)	32 (3)	20 (3)
Survey151	38 (3)	360 (3)	40 (3)	175 (3)	67 (3)	111 (3)	127 (3)	43 (3)	44 (3)	57 (3)	61 (2)	55 (3)	26 (2)	44 (3)	61 (3)	26 (3)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria.

the number of samples (max 3) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

1 m Samples

As seen in the Table 4 below, for this quarter, the near surface water (1 m) at section EE and sites D1, D2 and SYC would be deemed “unacceptable” for primary body contact essentially all of the time. Elsewhere, particularly to the south of the Inner Harbour, there were some unacceptable values that tended to abate as the quarter progressed. Interestingly there are no “unacceptable” values at the HP sites that would not be expected to be affected by the changes to the sewer system to date.

10 m Samples

Referring to Table 5, the 10m floating mean values for this quarter show “unacceptable” water quality consistently only at EE1, the site nearest to the Halifax outfall. The deep

outfall, depending on the status of the disinfection unit, may be increasing bacteria concentrations in the deeper water. Elsewhere there are sporadic "unacceptable" levels, but as with the 1m samples, the number of locations decreases with time through the quarter.

Task Force Guidelines

Most of the sites that are regularly deemed unacceptable for swimming are in the Inner Harbour that is classified SC by the Halifax Harbour Task Force. There are no Task Force limits on bacteria in this area. The greatest number of Task Force guideline exceedances, normally occur in the class SB areas just outside the Inner Harbour; that is, in the southern Basin, Black Rock Beach and the Northwest Arm, particularly the PC and RNSYS sites. This quarter there were class SB exceedances only to the south of the Inner Harbour. The most significant were at BRB and Eastern Passage. The sites within the Task Force "Outer Harbour" boundaries are B2, HC and the HP section. This quarter neither HC nor the HP sites meet the SA criteria at any time. This quarter, site B2 meets the SA criteria almost all of the time.

4.2 Ammonia Nitrogen

Ammonia nitrogen is an important component in the nutrient balance in an estuary, and in high concentrations has potential for toxic effects; however, there is currently no marine water quality guideline for ammonia (CCME, 1999). The values obtained for this period are shown in Table 6. In addition, the quarterly mean and max values are plotted by station in Figure 7. The laboratory "reportable detection limit" (RDL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the RDL/2, or 0.025 mg/L was used for values below detection. Missed samples are excluded from the calculations.

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. In this quarter, at 1 m, 73 % of samples had detectable levels of ammonia and at 10 m, 66 % of samples had detectable levels. The mean value over the quarter is about 0.055 mg/L or just over the detection limit. There is no clear spatial pattern except that the values are lower in the Outer Harbour at site B2. In this quarter, the week-to-week variability is not significant, but there is a trend to lower values at the end of the quarter. This may be affected by the spring phytoplankton bloom that is occurring at the end of the quarter. Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

Table 6. Ammonia nitrogen summary (mg/L).
Note: green highlights indicate values below detection limits (0.05 mg/L). For statistics 0.025 mg/L was used for values below detection.

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
146 (3 Jan 08)	ND	0.06	0.08	0.07	0.07	0.07	0.08	0.07	0.08
147 (15 Jan 08)	ND	0.08	0.17	0.11	0.06	0.09	0.08	0.10	0.17
148 (30 Jan 08)	ND	0.07	0.09	0.08	0.07	0.08	0.08	0.08	0.09
149 (12 Feb 08)	ND	ND	0.08	0.06	0.06	0.07	0.11	0.05	0.11
150 (26 Feb 08)	ND	0.06	0.12	0.05	0.05	0.06	0.07	0.06	0.12
151 (11 Mar 08)	ND	ND	ND	ND	ND	ND	ND	ND	ND
mean	0.03	0.05	0.09	0.07	0.06	0.07	0.07	0.06	
max	0.03	0.08	0.17	0.11	0.07	0.09	0.11		0.17

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
146 (3 Jan 08)	ND	0.06	0.06	0.08	0.07	0.07	0.07	0.07	0.08
147 (15 Jan 08)	ND	0.07	0.06	0.09	0.1	0.08	0.06	0.08	0.10
148 (30 Jan 08)	0.08	ND	ND	ND	0.11	0.06	0.06	0.08	0.11
149 (12 Feb 08)	ND	0.06	0.05	ND	0.08	0.07	0.13	0.06	0.13
150 (26 Feb 08)	ND	ND	ND	ND	ND	ND	ND	ND	ND
151 (11 Mar 08)	ND	0.06	ND	ND	ND	0.05	ND	0.02	0.06
mean	0.03	0.05	0.04	0.05	0.07	0.06	0.06	0.05	
max	0.08	0.07	0.06	0.09	0.11	0.08	0.13		0.13

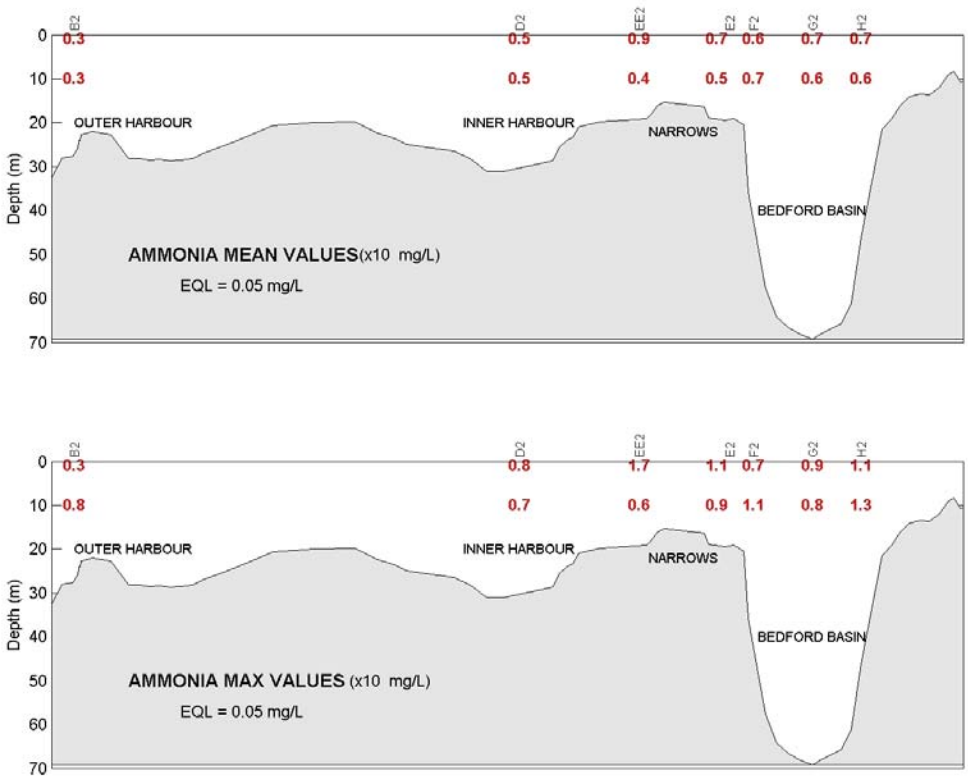

Figure 7. Mean and maximum values of ammonia nitrogen (X10 mg/L) over all fifteenth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis for regular samples ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. The supplementary sample (section 4.8) this quarter was analyzed for $CBOD_5$, but the concentration was below the detection limit.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were no samples that were below the RDL of 0.5 mg/L. The quarterly mean and max values are plotted by station in Figure 8. This quarter's site average values were in the range of 3.1-5.3 mg/L. The maximum values, by site, ranged from 4.3-10 mg/L. Overall, as with ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field

Table 7. TSS Summary (mg/L).

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
146 (3 Jan 08)	4.0	3.1	6.7	4.0	6.3	2.8	4.4	4.5	6.7
147 (15 Jan 08)	5.0	1.0	7.7	3.0	2.8	2.0	2.4	3.4	7.7
148 (30 Jan 08)	12.0	10.0	4.7	5.4	8.0	8.2	4.0	7.5	12.0
149 (12 Feb 08)	4.1	1.6	4.0	3.2	4.8	3.1	3.0	3.4	4.8
150 (26 Feb 08)	3.0	2.9	3.0	6.2	5.0	2.0	5.0	3.9	6.2
151 (11 Mar 08)	2.6	3.6	3.4	4.0	4.0	6.2	6.1	4.3	6.2
mean	5.1	3.7	4.9	4.3	5.2	4.1	4.2	4.5	
max	12.0	10.0	7.7	6.2	8.0	8.2	6.1		12.0

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
146 (3 Jan 08)	2.0	3.0	7.2	2.0	2.3	5.9	1.2	3.4	7.2
147 (15 Jan 08)	3.3	7.0	3.1	2.7	3.0	6.1	2.3	3.9	7.0
148 (30 Jan 08)	6.0	3.2	7.0	12.0	6.2	7.0	6.0	6.8	12.0
149 (12 Feb 08)	2.0	2.0	1.9	5.0	2.2	2.8	5.9	3.1	5.9
150 (26 Feb 08)	2.2	5.3	3.3	6.0	2.2	2.9	2.6	3.5	6.0
151 (11 Mar 08)	3.0	3.8	6.1	3.8	3.4	4.1	2.0	3.7	6.1
mean	3.1	4.1	4.8	5.3	3.2	4.8	3.3	4.1	
max	6.0	7.0	7.2	12.0	6.2	7.0	6.0		12.0

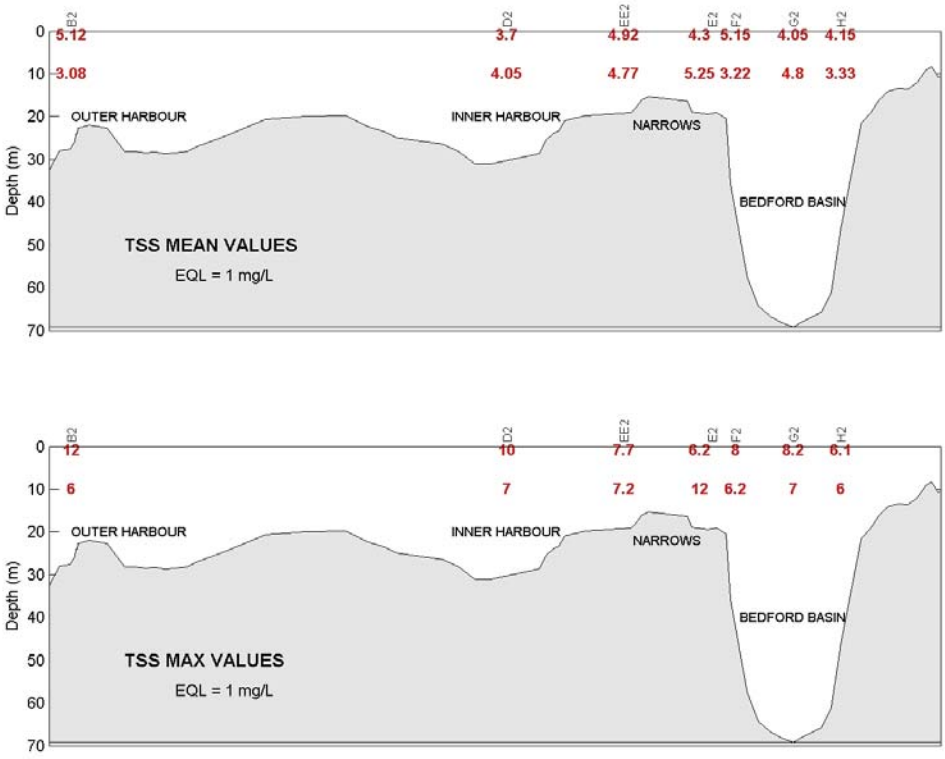

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all fifteenth quarter samples.

notes. In this quarter all survey means were similar at about 4 mg/L, except for survey 148 (30 Jan 08). In this survey stands out, the TSS levels were elevated everywhere and the survey mean (7.1 mg/L) was nearly twice the quarterly mean (4.3 mg/L). The spring phytoplankton bloom was occurring in survey 151 (11 March 08). The effect might be seen in the Basin samples but it is not a strong signal in the TSS data.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for total oil and grease (TOG) was discontinued in, survey 73 (23 Nov 06). The analysis is retained for supplemental samples. There was no TOG analysis this quarter.

4.6 Metals

The results of the metals analysis are summarized in Figure 9. For this plot the non-detectable values are considered zero. Through the whole quarter there were six guideline exceedances. Two were copper, at H2-1m in Survey 146 (3 Jan 08) and at B2-10m in survey 150 (26 Feb 06). The remainder were mercury and all occurred in surveys 149

and 150. These surveys were unusual in that all samples had detectable levels of mercury (> 0.01 µg/L). Aside from these samples this plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead and nickel are occasionally detectable, while cadmium was not detected. Iron is regularly detected, but has no guideline. Note that cobalt is also measured but has no guideline and is not regularly detectable, so it is not reported. The metal regularly closest to the exceedance level is copper with a mean value under 20% of the guideline.

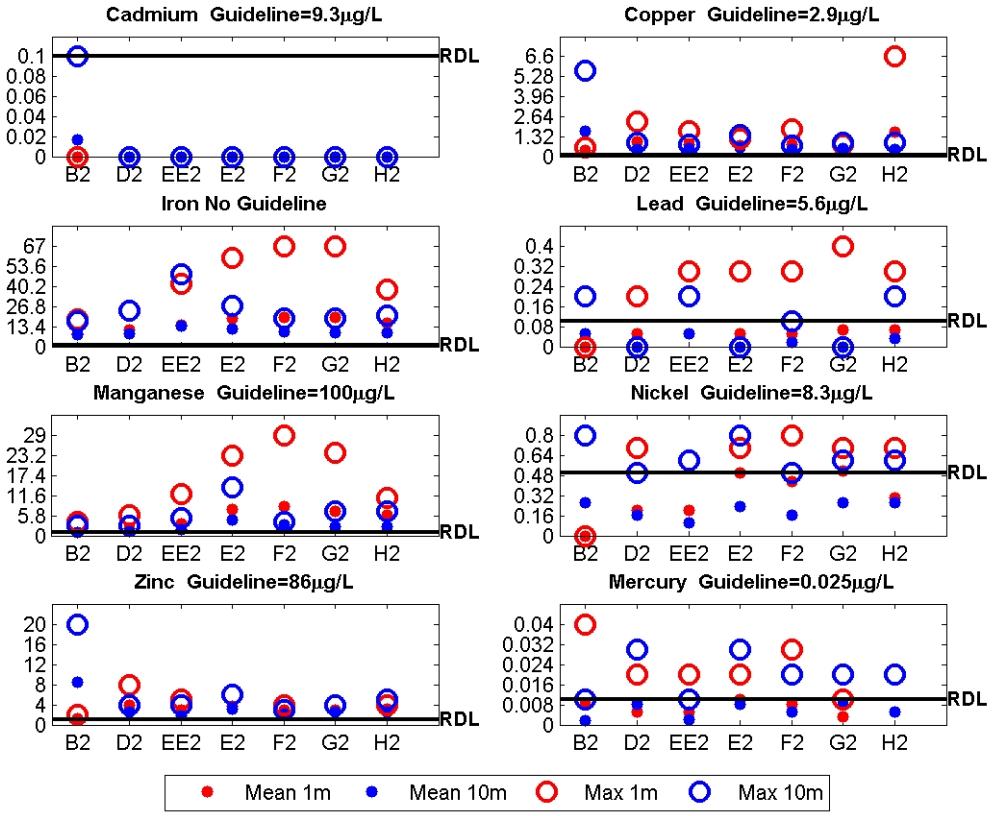

Figure 9. Mean and maximum values of metals (µg/L) over all fifteenth quarter samples.

4.7 Profile Data

The CTD used in this program measures continuous profiles of temperature, salinity, fluorescence and dissolved oxygen with depth. In early quarterly reports (up to Quarterly Report 8) the profile data was compared to the BBPMP data from the centre of Bedford Basin. This provided a check on the ranges and quality of the data collected for this survey. BBPMP has discontinued the time series contour plots so this comparison is no longer feasible. However, the contour plots of profile time series are useful in visualizing

the longer term variation in the state of the harbour. These plots are continued in the annual summary section of every fourth quarterly report (12, 16 and 20).

4.7.1 Salinity and Temperature

The temperature, salinity and density (derived from temperature and salinity) profile data provides valuable information on the physical state of the harbour that is very useful in interpreting the water quality data in the weekly surveys. The data is discussed in that context in the survey reports. As time series, the data is useful in characterizing changes in the state of the harbour on meteorological (storms etc) and seasonal timescales. The most interesting point is probably the centre of Bedford Basin as this reflects not only the near surface (upper 20 m) response to wind and rain, but also shows the effects of the periodic intrusion of dense shelf bottom water into the Basin (forced by local and shelf-wide meteorological events). This longer term variation is discussed in the annual summaries.

4.7.2 Fluorescence

The HHWQMP reported values of chlorophyll *a* are un-calibrated, generated using the default values provided with the Seabird instrument software. As such, though the units are mg/m^3, they are really more of a measure of fluorescence than of a true measure of the mass concentration of phytoplankton. The conversion to biomass is highly dependant on many factors, including species and condition of plankton present, and is approximate even when fully calibrated with water samples. However, the un-calibrated fluorescence values can be useful when considered on a relative basis. This comparison is probably more valid within a survey, where conditions are more likely to be consistent over the harbour, than between surveys which occur under different conditions. The more separated in time and space, the more uncertain the comparison. Nonetheless, due to the large variability in natural plankton concentrations, the data provides useful information on the relative spatial and temporal variability of phytoplankton activity.

The phytoplankton in Halifax Harbour generally exhibit more or less typical estuarine behaviour in the winter. That is, low productivity (<5 mg/m^3) during the winter followed by the strongest bloom of the year (40-80 mg/m^3) as sunlight returns in the spring (typically March). After the spring bloom, when light is plentiful, the behaviour seems to be affected by anthropogenic nutrient input. There are sporadic phytoplankton blooms throughout the summer and into the fall. These blooms can be close to the spring bloom in magnitude (30-40 mg/m^3) and occur until the drop in light levels in late fall and winter. There is a less distinct fall bloom that does not appear to be significantly different in intensity, based on fluorescence, than the blooms occurring throughout the summer. Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour.

At the start of this quarter the fluorescence levels were at about annual minimum levels (< 3 mg/m^3). This started to increase in Survey 150 (26 Feb 08) and spring bloom was definitely occurring by survey 151 (11 Mar 08).

4.7.3 Dissolved Oxygen

Comparison between dissolved oxygen determinations by different methods/instruments has proven uncertain. Part of this uncertainty is due to the vagaries of the instruments themselves. Additionally, small variations in processing procedures, particularly with "alignment" procedures, that assign depths to the DO measurements obtained with the CTD, can add uncertainty. The CTD sensors are quite stable, but tend to lose sensitivity with time. Due to the nature of the CTD itself, they cannot be user calibrated. The BBPMP routinely collects water samples for ground truthing their CTD DO measurements. The samples are analyzed with a well calibrated bench top DO meter. This data can be used to adjust the profile data. The BBPMP publishes the weekly profile data on their website.

As discussed in section 3, during this quarter there were problems with the DO sensor on the project CTD resulting in unscheduled maintenance. The sensor was removed from the CTD for three surveys. In place of the CTD DO data, a handheld YSI DO probe was used to collect surface values. This was supplemented with other publically available data (e.g. BBPMP, and the LOBO buoy). Upon return of the instrument, there were some continued stability issues and questionable values. The YSI surface measurements were continued. Overall this has resulted in a variety of DO data for this quarter. The week-to-week variations in the type and quality of the data are discussed in the relevant survey reports (146-151).

The Harbour Task Force Class SA, SB and SC water use classifications have guidelines for dissolved oxygen of 8.0, 7.0 and 6.0 mg/L respectively. Class SA pertains to the Outer Harbour and Class SC pertains to the Narrows and Inner Harbour. The remainder of the harbour is classified as SB. Based on the interpretation of the relatively limited data available, the DO over this period appeared to meet the appropriate guidelines everywhere, most of the time. The exception, as usual, is the deep water in Bedford Basin that is below the 7.0 mg/L level all quarter until the final survey. This survey indicates that the bottom water has been renewed by an intrusion of well oxygenated water. In survey 150 there was also water just below the 7.0 mg/L guideline at the bottom at section C.

4.8 Supplemental Samples

Halifax Treatment Plant Outfall

On survey 150 (26 Feb 07), a supplemental sample was taken in a visible boil and detritus patch over the Halifax STP outfall. The plume was very visible from a distance and extended most of the way across the Harbour (Figure 10). Upon approaching, there

were congregations of gulls and visible boils over the outfall's diffuser (Figs. 11 and 12). The water quality in the plume was visibly deteriorated with patches of scum on the surface and relatively large particulates (Figs 13 and 14). A 1m sample and a CTD cast was taken at 12:24 AST at a site near the outfall (44° 39.248' N, 63° 34.402' W) almost 200 m from shore. This sample was analyzed for Fecal Coliform, TSS and $CBOD_5$. Given the plume appearance, the results of the analysis, shown in Table 8, are surprisingly unremarkable. The values are in line with the other samples in the survey.

The visibility of a freshwater effluent plume in salt water is very difficult to predict. The diffuser on the Halifax STP is designed for a nominal 50:1 dilution. The nominal dilution depends on the assumed design conditions but the actual dilution can vary widely around those design conditions. The actual dilution at a given time is a strong function of the flow rate and the existing oceanographic conditions that can both vary substantially. The actual dilution in for some outfalls can vary by more than a factor of 10. Assuming the nominal 50:1 dilution, that there is sufficient water movement that the water flowing past the outfall is essentially at ambient temperature and salinity conditions and that the water column is uniform the plume will be approximately 0.6 PSU fresher than the surrounding water. This is an easily measurable difference and under the right environmental conditions will cause a discrete plume.

If the water column is stratified the salinity difference will be less and the plume may reach neutral buoyancy below the surface and have no surface signature. If, however, there is not enough flow past the diffuser to provide ambient conditions at the upstream edge of the diffuser, the effluent will not be removed over the diffuser and the vertical entrainment from the outfall can create its own environment. The discharge results in a net flow in toward the diffuser at the bottom and the diluted effluent forms a plume spreading away from the outfall at the surface. The surface water will eventually be a 50:1 dilution of freshwater with bottom water (i.e. about 0.6 PSU less saline than the bottom water). This water, though less saline than the bottom water, may be significantly more saline that the ambient surface water in the harbour. This is what appears to be happening here. Figures 15 and 16 show the salinity and temperature profiles respectively. These are at the sample site, as well as from the regular sampling sites both up and down harbour from the outfall. The near-surface salinity near the outfall is higher than the salinity either up or down harbour, while the bottom salinity is as expected roughly between the two. The near-surface salinity is about what would be expected by a 50:1 dilution of freshwater with the bottom water. The temperature is a bit more complex, but the surface temperature is colder near the outfall than at either the up or down harbour sites, due to bottom water entrainment. The up-harbour (EE1) profile is quite close to the outfall and the temperature there may be affected by the plume. The sample was taken at about slack high water, suggesting that the effect of the plume may be more evident up-harbour. It appears that in this case the edges of the plume may be defined by fronts between the saltier, colder water in the plume and the fresher, warmer ambient surface water. This is somewhat speculative without further CTD profiles within the plume.

Effluent plumes are sometimes quite visible, often due to their affect on small capillary waves, or effluent colour. An effluent plume often looks like coastal wind shadow but on closer examination can be differentiated by visible fronts with strong gradations of colour, collections of detritus or other visible differences, as well as by the location of known sources. The reason for the effect on capillary waves is unknown to the author, but may be due to the chemical nature of the effluent (surfactants?) or the spreading velocity of the plume or some other phenomenon. It has been suggested that the visibility may in part be due to differences in refractive index that is a function of salinity. The limit of visibility depends on many factors including, but perhaps not limited to, effluent dilution, the chemical character of the effluent, the density difference with receiving water, light intensity, the angle of the viewer and the sun angle. Under the right conditions very subtle differences in characteristics may be visible

Table 8. Halifax STP outfall sample, lab results (26 Feb 08).

	UNITS	1m	RDL
BACTERIA			
Fecal Coliform	cfu/100mL	240	1
INORGANICS			
Carbonaceous BOD	mg/L	ND	5
Nitrogen (Ammonia Nitrogen)	mg/L	ND	0.05
Total Suspended Solids	mg/L	4.0	0.5

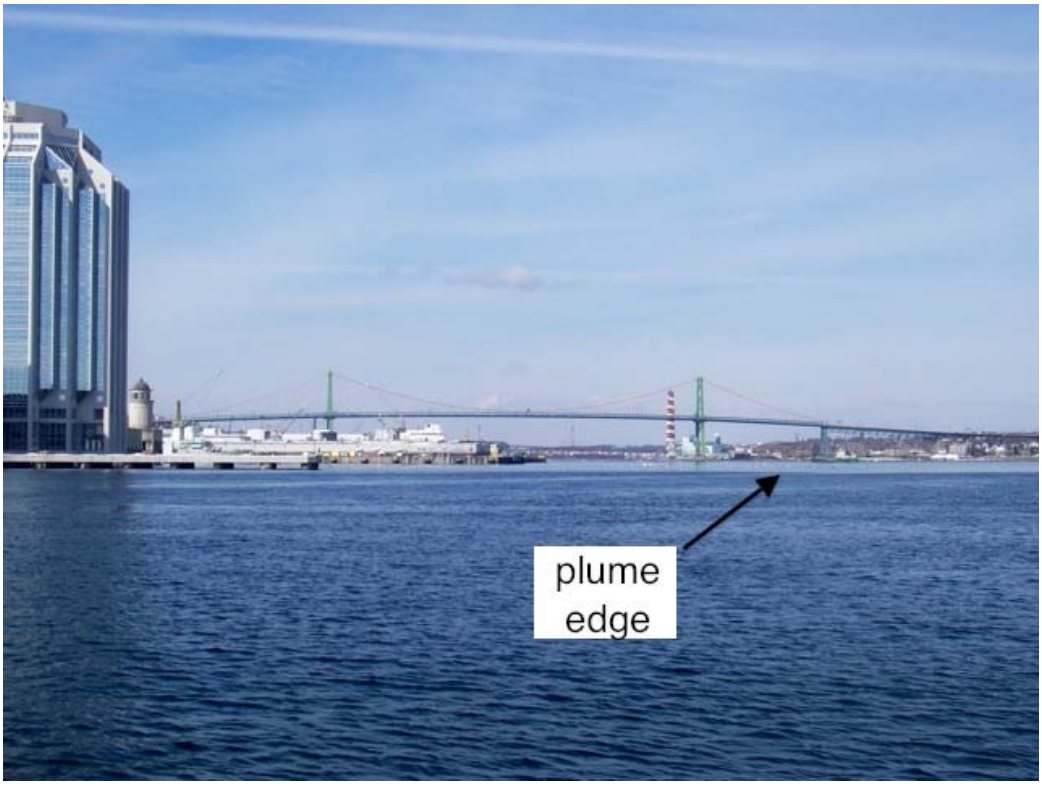

Figure 10. Visible plume from down harbour.

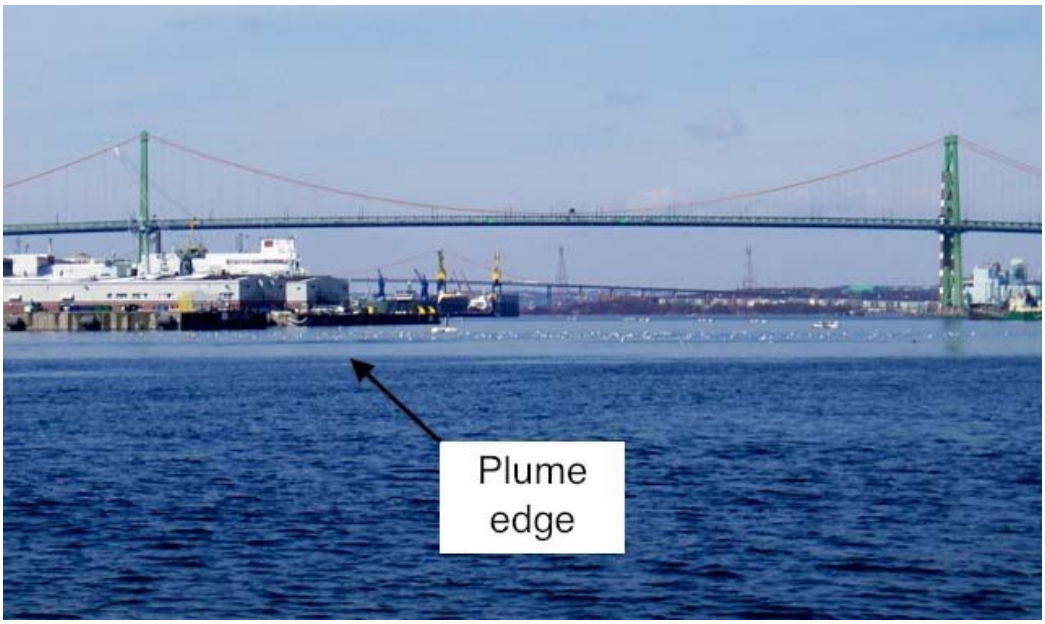

Figure 11. Plume edge and birds approaching outfall.

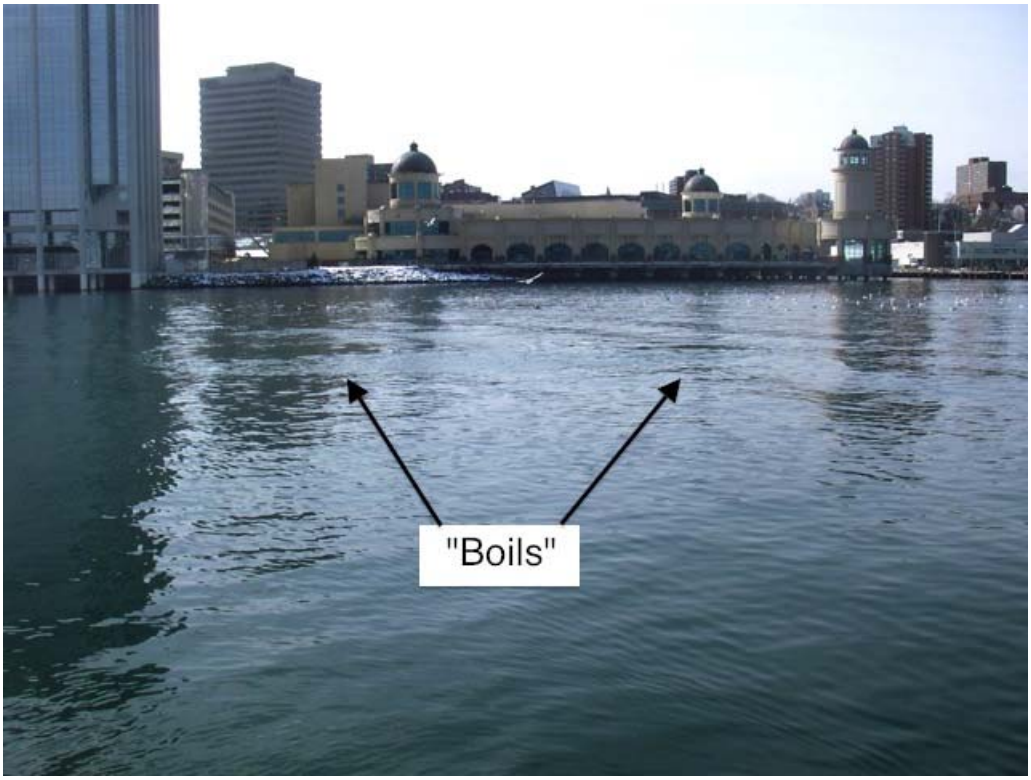

Figure 12. Surface boils over diffuser.

Figure 13. Scum at surface.

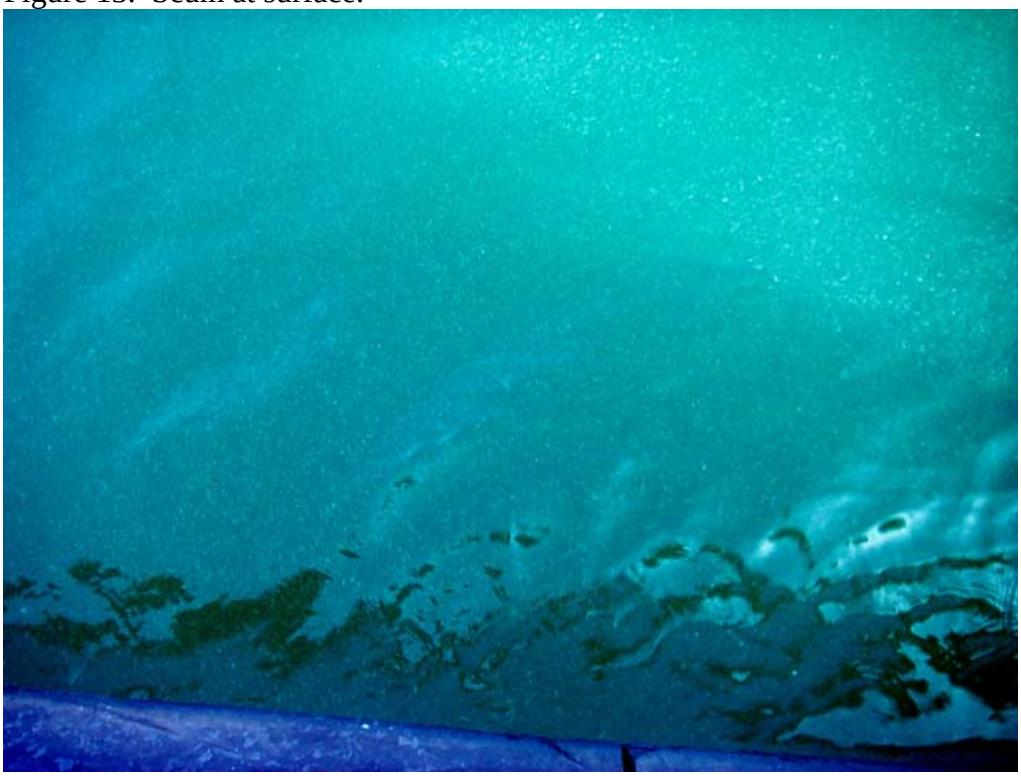

Figure 14. Particulates/flocs in water column.

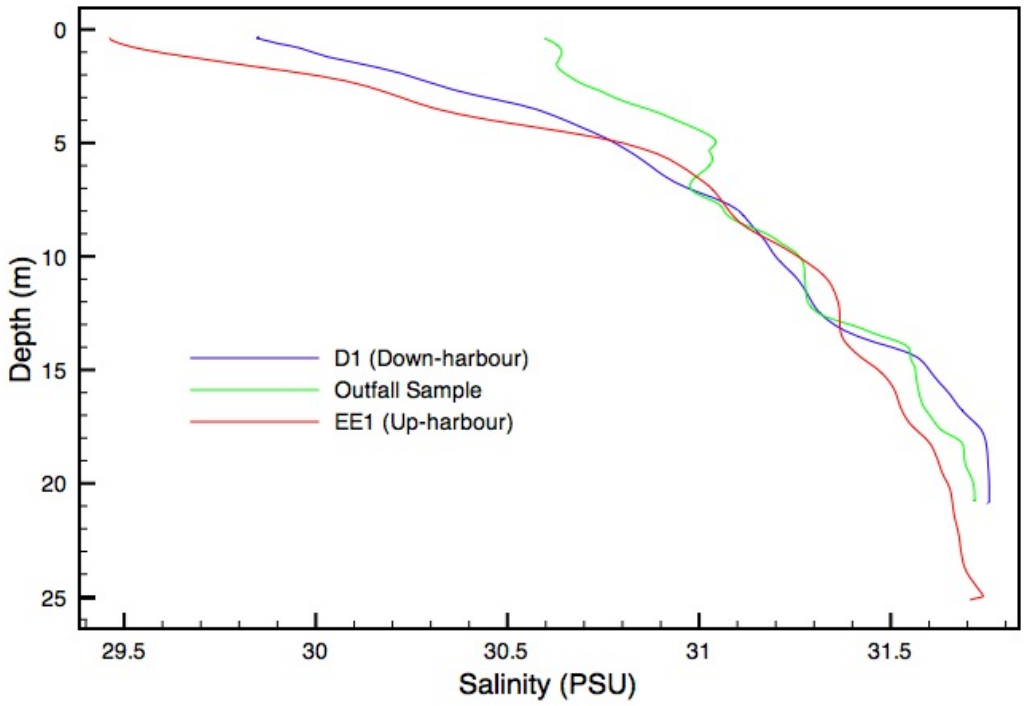

Figure 15. Salinity profiles at the outfall sample site, D1 and EE1.

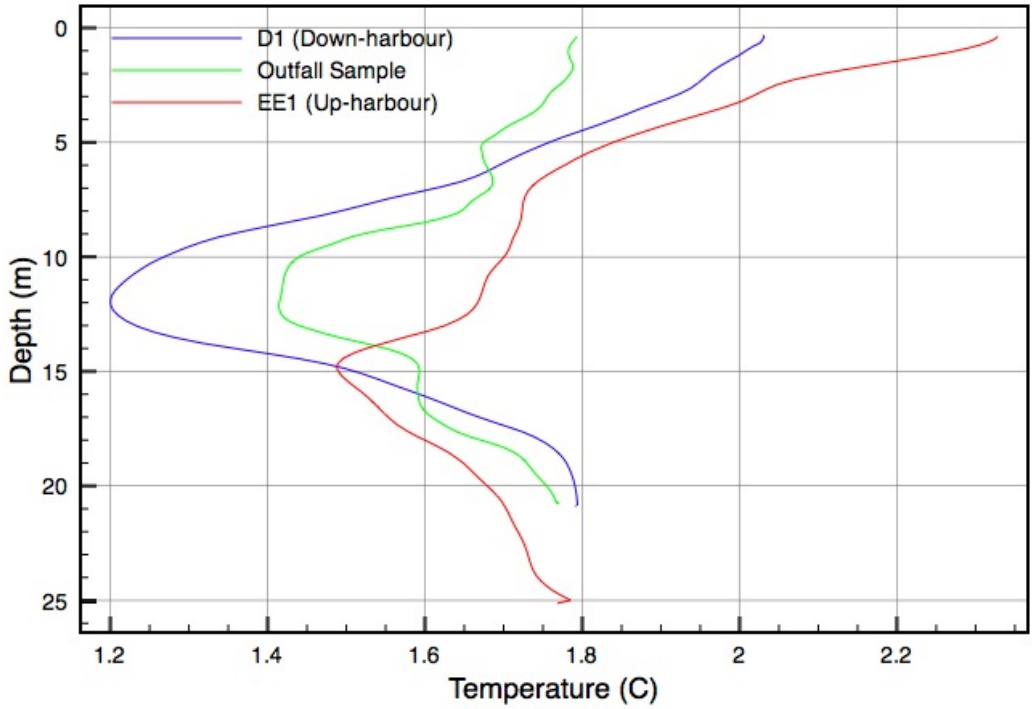

Figure 16. Temperature profiles at the outfall sample site, D1 and EE1.

5 Summary

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter and any new or ongoing issues.

5.1 Reporting

Survey Reports

The report analysis/presentation has been refined and is essentially in final form. There may be periodic changes required to accommodate any changes in data collection. At the end of this quarter a table comparing CTD DO data with surface YSI data as well as data from BBPMP and the LOBO buoy has been added to the cover sheet of the survey data files. This results in a survey specific scale factor for the DO data.

Changes
- None

Quarterly Reports

The Quarterly report discussion is limited to the data of that quarter. Every fourth Quarterly report includes a section reviewing the data over the last year. Each quarterly report contains a discussion of any supplementary samples taken in the quarter.

Changes
- None

5.2 Sampling Program

The sampling route selection continues as per the end of the ninth quarter. As of that time the routes were modified to always either start or end in the Northwest Arm, where the survey boat is based. This was done based on travel time considerations and does introduce an early morning/late afternoon bias into the NW Arm data. The morning sampling may coincide with the peak diurnal sewage flows and may result in a bias in water quality samples near the chain rock outfall (e.g. RNSYS, PC). This is also a function of the plume trajectory at the time of sampling. This should be considered in a detailed analysis of RNSYS and PC water quality data. This quarter the regular collection of handheld YSI DO data for purposes of ground truthing has begun. The sampling sites remain as at the end of quarter 10. The last change has been the addition of the HP sites. The sample analysis remains the same as at the end of quarter nine. The last modification was the addition of the high resolution metals analysis.

Changes
- None

5.3 Water Quality Parameters

Fecal Coliform

In general, the geometric mean coliform values are well above primary contact guidelines in the Inner Harbour. Outside of the Inner Harbour high values are more sporadic. The occurrence of high values outside the Inner Harbour are primarily dependant on oceanographic conditions that may transport water from the Inner Harbour either up or down harbour, and secondarily dependant on loading events (e.g. storms) that may increase loads thereby raising levels everywhere. Both of these often act together. This quarter, the spatial distribution of fecal coliform is being affected by the ongoing connection of the sewers to the Halifax Treatment Plant (particularly from the NW Arm) and "debugging" of the UV disinfection system. The main effect visible in this quarter's data is a shift of the distribution to the south. A reduction in magnitude is not immediately obvious.

With respect to compliance with Task Force guidelines the most numerous exceedances are in the class SB rated areas adjacent to the Inner Harbour to the south. The class SA guideline in the Outer Harbour is generally not met at HC and the HP sites, likely due to the periodic influence of the Tribune Head outfall. The class SA guideline is met at B2 most of the quarter.

As of last quarter, there has been additional bacteria monitoring initiated in the Northwest Arm. The purpose is to establish storm-induced transients in the Arm. This is not strictly part of this project and the data is reported under separate cover. The monitoring includes surface samples for both fecal coliform and enterococci. This data will allow a comparison of the two tracers and if desired to evaluate the use of fecal coliform for a proxy for enterococci in the Harbour. The current Canadian Environmental Quality Guidelines (ceqg-rcqe.ccme.ca) recommend enterococci over fecal coliform as a tracer of human waste contamination in salt water.

Changes

- None

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. Overall, in this quarter; just over 66% of samples had detectable levels of ammonia. The values are generally relatively uniform throughout the harbour except they are somewhat lower in the Outer Harbour at B2. There is definite temporal variability. The reason for the temporal variability is not clear. There does not seem to be a simple correlation between ammonia concentrations and meteorological/oceanographic

conditions, as is evident in the coliform data. In this quarter the last survey (151, 11 Mar 08) had significantly lower values. This could be related to the spring bloom.

Ammonia nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and, therefore, has quantifiable source strength in sewage. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the Harbour oxygen dynamics, additional species of nitrogen should continue to be considered for monitoring.

Changes
- None

$CBOD_5$

Based on recommendations in Quarterly Report 2, $CBOD_5$ was dropped from regular analysis in survey 49 (25 May 2005). Until that time there were an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program. This quarter there was one supplemental sample analyzed for $CBOD_5$ that had concentrations below the detection limit.

Changes
- None

Total Suspended Solids

The TSS values in the harbour are generally moderate with no obvious strong correlation in space or time with oceanographic or sewage loading conditions. This quarter the survey means were about 4.0 mg/L. The exception is survey 148 that has a mean about twice that high. The reason is not clear. There are at times higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. In survey 151 (11 Mar 08) spring bloom is occurring but there is no appreciable signal in the TSS data.

Changes:
- None

Total Oils and Grease

Based on recommendations in Quarterly Report 5, total oil and grease (TOG) was dropped from regular analysis in survey 75 (23 Nov 05), due to lack of detection. It is retained in supplemental sample analysis. This quarter there was no TOG analysis.

Changes
- None

Metals

In general the metals with guidelines are present at levels well below the guidelines. The metal that is consistently closest to exceeding the guideline is copper. In this quarter there were six guideline exceedances. Two were copper. The mean copper values are less than 20% of the 2.9 µg/L guideline. Four were mercury. These were unusual they occurred in two consecutive surveys (149 and 150) where all samples had detectable levels. Mercury is seldom detectable at the 0.01 µg/L RDL. The current metals analysis seems to be generally resolving the concentrations of important metals.

Changes:
- None

Fluorescence

Un-calibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the Harbour. The HHWQMP data allows for the gross identification of phytoplankton activity and is particularly useful in the interpretation of the DO data. The fluorescence data could also be useful to add a spatial interpretation to the detailed phytoplankton analysis at the BBPMP site.

In the beginning of this quarter there was minimal phytoplankton activity (<3 mg/m^3). The fluorescence levels increased in the last two surveys due to spring bloom.
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Changes
- None

Dissolved Oxygen

To date, oxygen levels as measured in the program, are generally relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. This quarter due to instrument issues the DO data was limited. The available data indicates conformance with applicable guidelines except in the deep basin waters for most of the quarter. There was an intrusion of well oxygenated water,

measured in the last survey, which brought the deep water above the 7.0 mg/L guideline. There are continuing issues of DO sensor calibration/ground truth (Section 4.7.3).

Changes

The regular collection of surface DO levels, with a handheld YSI meter, for purposes of ground truthing the Seabird CTD data began on survey 151 (11 Mar 08). These data and associated derived scale factors are presented on the cover sheets of the individual survey data files.

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